



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE  
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

Group Art Unit: 3723  
Examiner: Anthony Eziamara OJINI

In Re PATENT APPLICATION Of:

**Appellant(s):** Patrick Michael McCaffrey et al.

Serial No.: 09/840,077

Filed: April 24, 2001

For: POWDER FOR DISKS

Docket No.: IBM-204

BRIEF ON APPEAL

January 14, 2005

**MAIL STOP APPEAL BRIEF - PATENTS**  
**Commissioner for Patents**  
**P.O. Box 1450**  
**Alexandria, VA 22313-1450**

Sir:

## INTRODUCTION

This is an Appeal from the Final Office Action dated August 24, 2004. This Brief on Appeal is being filed within two months from the date of filing the Notice of Appeal (November 15, 2004) and requisite fee, and is being filed together with the fee as required by 37 CFR §41.20(b)(2). Should no remittance be attached or if any additional fees are needed, please charge the same to our deposit account no. 18-0002 and advise us accordingly.

The Examiner rejected all pending claims 1, 4-9, 21, and 23-28. The other claims 2, 3, 10-20, 22, and 29 were canceled without prejudice to reentry. A copy of the claims involved in this Appeal is attached as Appendix A. Claims 10-20 were restricted, and the Appellants have maintained traversal of the restriction requirement, as is explained in Appendix B.

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#### REAL PARTY IN INTEREST

The present application has been assigned to International Business Machines Corporation, of Armonk, New York 10504, which is the real party in interest.

#### RELATED APPEALS AND INTERFERENCES

To the best of the undersigned attorney's belief and knowledge, no other appeals or interferences are or have been filed which may be related to, directly affect, be directly affected by, or have a bearing on the Board's decision in the pending appeal.

#### STATUS OF THE CLAIMS

This application was filed on April 24, 2001, with apparatus claims 1-9 and method claims 10-20. The method claims 10-20 were examined, and subsequently restricted and canceled (see Appendix B), and new apparatus claims 21-29 were added, by the Amendment of December 3, 2003. Claims 2, 3, 22, and 29 were canceled by the Amendment of June 22, 2004.

All the pending claims 1, 4-9, 21, and 23-28 are apparatus claims, with 1, 9, and 21 being independent. All the pending claims are rejected in the Final Office Action herein appealed from, of August 24, 2004.

Claims 1, 4-9, 21, and 23-28 are pending in the application.

Claims 1, 4-9, 21, and 23-28 have been finally rejected.

Claims 1, 4-9, 21, and 23-28 are appealed.

#### STATUS OF AMENDMENTS

No amendments have been filed subsequent to the Examiner's final action.

## SUMMARY OF CLAIMED SUBJECT MATTER

Disks made of brittle and easily-scratched materials, such as glass or glass ceramic, are important for making computer hard drives and similar items; these disks can store digital information after they are coated with a thin layer of magnetic material. The Appellants' specification notes (page 1, line 16 and page 8, line 11) that in a magnetic disk the information density depends on having the reading head fly very close over the surface of the hard disk. But closeness depends on a smooth, flat, and undamaged surface. Non-brittle metals, such as aluminum and nickel, are not as suitable for hard drive disks (Appellants' specification at page 1, line 20 and page 2, lines 2-9).

Thus, high information density requires an un-damaged surface of a hard and brittle disk, and the surfaces of these disks must be kept in good condition during transportation and processing.

In order to be transported without taking up an inordinate volume of space, and also to facilitate automatic processing (e.g., in clean rooms), hard drive disks must be *stacked* on one another, rather than being packaged individually (page 2, lines 18-21). However, hard and brittle disks that are stacked directly one on top of one another are very likely to chip or break each other during the rough handling of transport, and scratches are certain to result when hard particles get in between the disks. Furthermore, very clean and very flat hard objects tend to stick together on contact, and hard drive disks are likely to stick if not kept separated (page 3, line 1).

The conventional way to prevent disk sticking and damage is to insert sheets of paper between the disks, but paper has caused problems, including paper falling into the machinery and being counted or treated as a disk (specification pages 3-4). There has been a need for something better (page 4, lines 8-11).

The Appellants solved the paper problem by using powder in place of paper sheets (Fig. 2 shows powder between two disks 12). The powder cushions the disks and absorbs impacts better than paper (the Honorable Board is invited to compare a bean-bag chair to a stack of newspaper); the powder prevents them from sticking together; and it does not get stuck in the handling machinery, as paper does (page 5, lines 5-11 and page 9, lines 5-22). When un-stacking the disks, the powder can be blown off and/or removed as part of the polishing operation (page 5, lines 12-18).

The Appellants have simplified and advanced the art, and the Appellants' solution is *very simple*. Such simplicity makes inadvertent hindsight reconstruction a very easy thing to fall into, and it is respectfully submitted that hindsight reconstruction is the basis of the Examiner's rejection. As the Appellants will demonstrate by their arguments below, the prior art does not disclose or suggest their powder.

Specific embodiments of the Appellants' powder include: inorganic powder (claims 4 and 24; supported at page 5, line 19); calcium carbonate, mineral, and specific powder materials (claims 5-7 and 25-27; page 6, lines 8-16); powder mesh 200 (claims 8 and 28; page 6, last paragraph and page 11, lines 14-18). Transport cassettes are disclosed at page 9, first paragraph). Powder softer than the disks is disclosed at page 6, line 6.

#### GROUND OF REJECTION TO BE REVIEWED ON APPEAL

1. Claim 9 is rejected as being indefinite under 35 U.S.C. § 112, second paragraph.
2. Claims 1, 4-9, 21, and 23-28 are rejected under 35 U.S.C. § 103 as being unpatentable over Schweitzer et al (US 3,856,472) ("Schweitzer") in view of Kojima et al (US 3,990,990) ("Kojima").

ARGUMENT: INDEFINITENESS OF CLAIM 9

It is curious that the Examiner has rejected claim 9 for “glass *or* ceramic-glass” while not rejecting the other two independent claims 1 and 21 for “comprised of *one of* a glass *and* glass ceramic,” which has exactly the same meaning. The meaning is the same whether “or” is taken in its exclusive sense, or in its inclusive (i.e., logical) sense. The latter statement is true because “comprised” in claims 1 and 21 allows the non-selected element to be encompassed by the claim language, and so the case of *both* glass and glass ceramic is covered, just as that case is covered by inclusive “or.”

With respect, the rejection appears to be based on the Examiner's incorrect opinion that “or” is inherently indefinite under § 112, while “and” is not. Such an assumption is contrary to M.P.E.P. §§ 2173.05(h)(II) and 2173.04, is contrary to USPTO practice, and is contrary to case law.

ARGUMENT: OBVIOUSNESS REJECTION OF CLAIM 1 (incorporated for 9 and 21)

**Obviousness Rejection:** Each one of the independent claims 1, 9, and 21 recites the main features of disks separated by powder. The Appellants argue for all of theseinics, and each one of these claims individually, below.

Schweitzer discloses an apparatus for “gettering”<sup>1</sup> semiconductor wafers to “prevent or reverse the diffusing-in of impurities” (col. 1, line 22). Schweitzer sandwiches each semi-conductor disk 5 between two quartz disks 6 in a stacked arrangement (shown in Fig. 2) and heats the stack in an oven at more than 1000 °C (col. 2, line 17). Impurity molecules diffuse from the semiconductor disks to the quartz disks, thus purifying the semiconductor wafers. The heat increases molecular speeds and thereby speeds the process of molecular diffusion, which is

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<sup>1</sup> The Random House Dictionary defines “getter” as “any substance introduced into a partial vacuum [e.g. a vacuum tube] to combine chemically with the residual gas in order to increase the vacuum.”

the basis of gettering impurities out of the semiconductor and into the quartz (col. 2, lines 26-31).

(1) The Examiner asserts that Schweitzer discloses disks of “glass and glass-ceramic” (page 3, line 3 of the final Action), but the Appellants believe that neither of these materials are actually disclosed.

First, as to “glass:” Although the reference refers to the disks 6 as “quartz glass” (col. 2, line 61), it also discloses that the disks are made of “quartz ( $\text{SiO}_2$ ).” Quartz, although it is an ingredient of glass and can be used for optical parts as glass is, it is by itself a crystalline substance, best classified as a ceramic rather than a glass. The other two materials mentioned at col. 1, line 62 as being as useful for gettering are silicon nitride and boron nitride, which are both ceramics. Attached as Appendix C are pages from the Encyclopaedia Britannica; page 196 of vol. 8, in the first paragraph of the Glass article in col. 2, states the basic fact of glass, i.e. that it is a non-crystalline liquid. The beginning of the second paragraph states that quartz ( $\text{SiO}_2$ ) is an ingredient of glass.

Second, as to “glass-ceramic:” Schweitzer nowhere mentions this term, and the Examiner has not cited to the reference as mentioning this term or disclosing the material. Furthermore, the Examiner appears to ignore the meaning of the claim terminology. A glass-ceramic is a special type of glass, not a pure ceramic like quartz, silicon nitride, or boron nitride. In Appendix C of pages from the Encyclopaedia Britannica, page 210 of volume 8 describes glass ceramic as a glass that has had special heat treatment; likewise, page 1154 of vol 3, in the third paragraph in col. 2, describes “glass ceramics” as a special material that is partly crystalline and formed from glass by heating. This shows that pure quartz cannot be classified as a glass-ceramic, because quartz has its own unique response to heat treatment, as is shown in Appendix C by the last paragraph in the middle column on page 341 of vol. VIII.

Thus, the reference discloses neither glass nor glass-ceramic.

(2) Schweitzer does not disclose powder, as the Examiner admits (page 3, line 4).

Moreover, Schweitzer teaches against powder.

Schweitzer states (col. 3, lines 6-17) that “gettering ... can be increased ... if ... the two surfaces in contact with each other are sufficiently flush so that the mutual deviations of the averaged surface from a geometric plane are not greater than the depth of the [surface] roughness.” The surface roughness is less than 15  $\mu\text{m}$  (claim 3). Schweitzer's claim 1 recites that the getter disks “lie in contact with the faces of said semiconductor discs.”

Clearly, when two touching surfaces are flat and smooth, impurity molecules will diffuse from the semiconductor into the quartz more quickly because they can diffuse directly across the material boundary, over a short travel path.

If sand (quartz powder) were substituted for Schweitzer's quartz disk, then there would be only a few points of contact between the materials. The average diffusion path for an impurity molecule would be much longer, and, consequently, diffusion would be greatly reduced. That result would be contrary to the object of Schweitzer.

Conversely, grinding the semiconductor disks into powder clearly would also be contrary to the object of producing a usable semiconductor disk free of impurities.

Thus, Schweitzer discloses no glass or ceramic-glass disks; and even if the quartz is incorrectly taken as anticipating a glass or ceramic-glass disk, the reference inherently teaches against grinding up the semiconductor; and if, on the other hand, the semiconductor is incorrectly taken as anticipating a glass or ceramic-glass disk, then the reference again inherently teaches against grinding up the quartz into sand. M.P.E.P. § 2144.01.

(3) The Examiner relies on Kojima for disclosing powder, and Kojima does so: but Kojima, like Schweitzer, teaches against powder. Indeed, Kojima teaches against powder overtly and directly.

Kojima at col. 1, lines 13-25, states, “It is known to use an anti-adhering agent [such as] powder [which is] applied either in the form of powder or ... aqueous suspension to surfaces of rubber ... Such the conventional treatments ... are disadvantageous because they usually cause dusting and produce bad working environments.” Kojima goes on (col. 1, lines 34-42) to announce that its object is to overcome the disadvantages of such known methods and to “provide a new and improved anti-adhesive composition for rubber which is of a *non-powder* form which never cause dusting” (emphasis added). Kojima provides an aqueous solution to replace powder.

However, Kojima also discloses (claim 14 and col. 3, lines 60-68) adding some powder to its aqueous solution. The powder might be talc, mica, calcium carbonate, or magnesium carbonate (col. 4, line 2). According to Kojima, the added powder will not cause dusting because the powder is “suspended in the aqueous solution” (col. 4, lines 1-8). Thus, Kojima teaches against the use of powder except when it remains in an aqueous solution.

Kojima's teaching is directly contrary to the recitation in claim 1 (and also the other two independent claims 9 and 21) that “only” powder is disposed between the disks.

Kojima *consistently* teaches against the Appellants' claim 1 (and also claims 9 and 21) throughout.

(4) Would the person of ordinary skill have been motivated by this teaching to substitute powder in an aqueous solution for either the quartz disks or the semiconductor disks of Schweitzer? The person of ordinary skill would be aware that the aqueous solution of Kojima would evaporate in the 1000 °C oven of Schweitzer, leaving a dry dust of talc, mica, calcium carbonate, or magnesium carbonate, contrary to the teaching of Kojima against dusting.

The person of ordinary skill would also be aware that none of the materials used by Kojima is mentioned by Schweitzer as a getter (Schweitzer mentions only boron nitride, silicon nitride, and silicon dioxide, i.e. quartz), and there is no evidence that Kojima's materials (talc,



mica, calcium carbonate, or magnesium carbonate) have an impurity solubility higher than the expected concentration of impurities in semiconductor materials, which is the criterion used by Schweitzer (col. 1, lines 55-57).

Also, as is discussed above, use of a powder in place of a disk would greatly reduce the diffusion which is the object of Schweitzer, even if Kojima's materials were suitable for gettering (which is not disclosed).

The Appellants respectfully submit that substituting Kojima's aqueous solution of talc, etc., for Schweitzer's disks would be completely useless, and would not have been done by a person of ordinary skill in the art, who knows everything technical.

(5) With respect, the Examiner's proposed motivation for combining the references is incorrect. "It would have been obvious," writes the Examiner (page 3, line 14) "to provide product of Schweitzer et al. with a powder ... in view of Kojima et al. so as to prevent the disks from sticking to each other." However, Schweitzer is not concerned with sticking and the Examiner provides no citation or other evidence showing that this is a concern to Schweitzer or in the semiconductor wafer art generally. There is no support for the Examiner's assertion, either by citation or by reasoned argument. A similar assertion is presented at page 4, lines 3-4, again without any support.

(6) Where Schweitzer is concerned with removing impurities from semiconductor wafers, Kojima is concerned with preventing unvulcanized rubber mats from sticking to each other, a field far from that of Schweitzer; the only similarity seen by the Appellants is that the wafers and the rubber sheets are both laminar. In every other way their properties are disparate, and this disparity also teaches against combining the references.

(7) The Examiner states on page 5, lines 18, that Kojima's powder "would inherently protect the substrate material surface from scratches, and serves to cushion the substrate material surfaces from impact damage." This is respectfully disagreed with. Particles of mica, talc, and

other minerals are much harder than rubber and would tend to scratch the rubber surface, not protect it; as to cushioning, the Appellants ask: is a rubber mat in need of cushioning? and if so, would a rubber mat be cushioned by tiny particles of grit? With respect, the answers are No.

(8) The concerns and objects of the applied artisans are irrelevant to the concerns and objects of the Appellants. For example, Schweitzer does not need to be concerned with chipping because the disks are held stationary in an oven, and Kojima's rubber mats cannot chip.

(9) The CCPA, in the case of *In re Buehler*, 515 F.2d 1134, 185 USPQ 781, wrote of the PTO's "attempt to take the plaintiff's invention apart bit by bit in order to show obviousness in each of its differences from the prior art. In determining patentability, however, we are not concerned with the obviousness of each bit when dissected out ... but with ... his whole invention as claimed." This case is cited in Appendix D.

#### ARGUMENT: OBVIOUSNESS REJECTION OF CLAIM 9

The arguments above are reiterated for independent claim 9.

#### ARGUMENT: OBVIOUSNESS REJECTION OF CLAIM 21

The arguments above are reiterated for independent claim 21.

#### ARGUMENT: OBVIOUSNESS REJECTION OF DEPENDENT CLAIMS 8 AND 28

As to the dependent claims 8 and 28, the Examiner states that the claimed 200 mesh powder is obvious as an optimum value, but neither reference mentions the powder mesh or teaches optimizing the particle size. Teaching toward optimizing particle size comes from the Appellants, not the prior artisans.

The case of *In re Rosenburger et al.*, 55 CCPA 880, 386 F. 2d 1015, 156 USPQ 24, concerned claims to producing a coating on a dinner plate. The CCPA wrote, "[PTO's] argument

assumes that Verela teaches that spraying the mold and dusting the preform are equivalent methods. This is incorrect, for Varela clearly teaches that the dusting and pill preform methods of coating yield unsatisfactory products. The teaching of Varela therefore discourages research in the very field where appellants made their invention.” This case is seen to support the Appellants' argument in the preceding paragraph.

#### FINAL CONCLUSION

In partial summary of the arguments above against obviousness:

(1) Neither of the references discloses either the glass material or the glass-ceramic material recited in the Appellants' independent claims, and therefore no combination could reach the claims, even if combination were obvious (not admitted).

(2) Both of the references teach against the use of the Appellants' claimed powder. The only reference which actually discloses powder (Kojima) actively and directly teaches against powder only, and teaches powder only when it is keep wet in special solution, which is impossible in the asserted combination; and the other reference (Schweitzer) teaches against powder inherently. There is no teaching at all in favor of powder, and the Examiner has not even asserted that there is such teaching, let alone pointed out any such teaching by citation or reasoned argument.

In partial summary of the arguments above against indefiniteness:

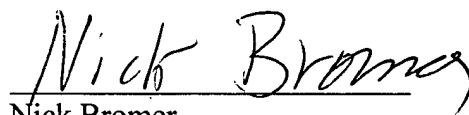
The rejection is inconsistent and contrary to the M.P.E.P.

Appellants have demonstrated that the Examiner's rejections of the claims as being indefinite or obvious in view of the cited patents lack basis in fact and in law. Appellant therefore respectfully requests the Honorable Board of Patent Appeals and Interferences to reverse or withdraw all of the rejections.

Respectfully submitted,

January 14, 2005

Date

A handwritten signature in black ink that reads "Nick Bromer". The signature is written in a cursive, slightly slanted style. The first name "Nick" is written above a horizontal line, and the last name "Bromer" is written below the line.

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APPENDIX A

Claim 1 (previously presented): In combination, a plurality of disks including a first disk and a second disk stacked upon said first disk, and a powder disposed between said first disk and said second disk, said powder facilitating removal of said first disk from said second disk, and protecting said first disk and said second disk from scratches, and serving to cushion said first disk and said second disk to protect said disks from impact damage, when said second disk is stacked upon said first disk,

wherein said first disk and said second disk are each comprised of one of a glass and glass ceramic; and

wherein only said powder spaces said first disk from said second disk.

Claims 2-3 (canceled).

Claim 4 (previously presented): The combination recited in claim 1, wherein said powder is comprised of an inorganic material.

Claim 5 (Original): The combination recited in claim 4, wherein said inorganic material is calcium carbonate.

Claim 6 (Original): The combination recited in claim 4, wherein said inorganic material is selected from the group consisting of calcium carbonate, calcium magnesium carbonate, calcium phosphate, magnesium carbonate, magnesium borate, magnesium oxide, magnesium phosphate, and clay.

Claim 7 (previously presented): The combination recited in claim 1, wherein said powder is a mineral powder.

Claim 8 (previously presented): The combination recited in claim 1, wherein said powder has a size of about 200 mesh.

Claim 9 (previously presented): In combination, a plurality of disks including a first glass or ceramic-glass disk and a second glass or ceramic-glass disk stacked upon said first disk, and a powder disposed between said first disk and said second disk, wherein said first disk is spaced apart from said second disk by only said powder.

Claims 10-20 (Canceled).

Claim 21 (previously presented): In combination, a plurality of disks including a first disk and a second disk stacked upon said first disk, and a plurality of fine, loose particles constituting a powder disposed between said first disk and said second disk, said plurality of fine, loose particles facilitating removal of said first disk from said second disk, and protecting said first disk and said second disk from scratches, and serving to cushion said first disk and said second disk to protect said disks from impact damage, when said second disk is stacked upon said first disk,

wherein said first disk and said second disk are each comprised of one of a glass and glass ceramic; and

wherein said first disk is spaced apart from said second disk by only said fine, loose particles.

Claim 22 (canceled).

Claim 23 (Previously Presented): The combination recited in claim 21, wherein said fine, loose particles space said first disk from said second disk.

Claim 24 (Previously Presented): The combination recited in claim 21, wherein said fine, loose particles are comprised of an inorganic material.

Claim 25 (Previously Presented): The combination recited in claim 24, wherein said inorganic material is calcium carbonate.

Claim 26 (Previously Presented): The combination recited in claim 24, wherein said inorganic material is selected from the group consisting of calcium carbonate, calcium magnesium carbonate, calcium phosphate, magnesium carbonate, magnesium borate, magnesium oxide, magnesium phosphate, and clay.

Claim 27 (previously presented): The combination recited in claim 21, wherein said powder is a mineral powder.

Claim 28 (previously presented): The combination recited in claim 21, wherein said fine, loose particles have a size of about 200 mesh.

Claim 29 (canceled).

## APPENDIX B

The Examiner examined all of the original claims 1-20 in the first Action dated September 10, 2002 but then in the second Action dated January 17, 2003, restricted the already-examined claims 10-20 on the grounds that the two “inventions” were related as “product and process of use.” However, this is incorrect; the actual relationship is product and method of making the product, as the Honorable Board can determine with a glance at original claims 1 and 10:

*1. In combination, a plurality of disks including a first disk and a second disk stacked upon said first disk, and a powder disposed between said first disk and said second disk.*

*10. A method of preparing a disk, comprising:*

*providing at least a first disk and a second disk;*

*stacking the first disk on the second disk; and*

*providing a powder between a surface of the first disk and a surface of the second disk.*

In the Action of April 17, 2003, the Examiner asserted that the requirement was proper because “the process of using the product can be practiced with another ... product,” which is also clearly incorrect. The claimed process of original claim 10 can only result in the claimed product of original claim 1, and nothing else.

The Appellants traversed the requirement in their Response of January 27, 2003, which incorporated a Petition to the Commissioner in case the restriction requirement were made final. However, nothing has been heard from the Commissioner in response to the Petition and the Appellants presume that the Examiner did not forward the Petition, despite reminders and requests for acknowledgment in the Appellants' Amendment of June 20, 2003 and the Amendment of December 3, 2003. In the Action of March 26, 2004 noted the Appellants' complaint that the Petition had not been forwarded to the Commissioner, and replied, “However, no Petition filed with the Applicants' response ... has been forwarded to the Commissioner,”



which does not constitute any explanation or clarification. The Appellants repeated their request in the Amendment of June 22, 2004. In reply (in the outstanding Action of August 24, 2004), the Examiner wrote that “the rules do not provide [for] such provisional petition ... applicant should file a petition with fees directly to Commissioner” (page 5, line 1).

Both of the Petitions were incorporated in other papers, but each was clearly captioned as a “PROVISIONAL PETITION” and 37 C.F.R. §1.181 does not require filing a petition as a separate paper, nor is the M.P.E.P. seen to include any such requirement—the Examiner has not identified “the rules” relied upon. If the Examiner *sua sponte* had instituted such a requirement, the Appellants should have been notified of this fact earlier. In any event, it is believed that examiners have access to copy machines and a copy could very easily have been, and in fairness should have been, forwarded by the Examiner to the petitioned authority.

M.P.E.P. 1002.01 states that “Petitions ... are sent to the [deciding] official,” which is the Tech Center Director under M.P.E.P. §1002.02(c)(2) and §1002.02(c)(3)(a) for the Appellants' petitions. However, the Appellants' Petitions specifically stated that they were appealing to the “Commissioner,” which is proper under 37 C.F.R. §1.181 (titled, “Petition to the Commissioner”). The Commissioner delegates to the proper official under M.P.E.P. §1002.02.

The Examiner also failed to forward a petition for withdrawal of finality sent to the PTO on October 3, 2003. No mention of this other petition is seen in the Examiner's actions.

APPENDIX C

Attached are pages photocopied from the Fifteenth Edition of the Encyclopaedia Britannica.

# The New Encyclopædia Britannica

in 30 Volumes

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Volume 8

Knowledge in Depth

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William Benton, Publisher, 1943-1973  
Helen Hemingway Benton, Publisher, 1973-1974

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VOL. 8

epoch. During the reigns of the Yung-cheng (1723-35) and Ch'ien-lung (1736-96) emperors, the emphasis on blown forms was subordinated to the desire to make glass a surrogate for natural stones. Although the colours used are often not those found in nature, the glass is handled as though it were jade, the foot of each piece, in particular, being fashioned as though cut from stone. This lapidary treatment is further emphasized in the cased glass bottles cut on the wheel in such a way that the design stands in one or more colours on a ground of a contrasting tone.

(R.J.Ch.)

**BIBLIOGRAPHY.** There is ample literature on the history of glass. The following selection of titles includes basic reference works and handbooks on glass and glassmaking, as well as some specialized studies. In addition, the *Journal of Glass Studies*, issued annually by the Corning Museum of Glass, includes extensive bibliographies. See also ROBERT J. CHARLSTON, *Masterpieces of Glass: A World History from the Corning Museum of Glass* (1980).

The basic sources for medieval glass manufacturing are HERACLUS, *Von den Farben und Künsten der Römer*, ed. by ALBERT ILG (1873); and THEOPHILUS PRESBYTER, *Schedula diversarum artium*, ed. by ALBERT ILG (1874; Eng. trans., *On Divers Arts: The Treatise of Theophilus*, 1963). GEORG AGRICOLA, *De re metallica* (1556; Eng. trans., 1912, reprinted 1950); and particularly ANTONIO NERI, *L'arte vetraria* (1612; Eng. trans. by CHRISTOPHER MERRET, *The Art of Glass* . . . 1662), give detailed descriptions of glassmaking in the 16th and 17th centuries. Other useful technological studies are APSLEY PELLATT, *Curiosities of Glass Making* (1849); and ALFRED LUCAS, *Ancient Egyptian Materials and Industries*, 4th ed. rev. (1962).

EDWARD DILLON, *Glass* (1907); ROBERT SCHMIDT, *Das Glas*, 2nd ed. (1922); and W.B. HONEY, *Glass: A Handbook* . . . *Victoria and Albert Museum* (1946), are among the best and most comprehensive general surveys of the history of glass. *Masterpieces of Glass* (1968), a catalog of some of the holdings in the British Museum, is a scholarly publication on the subject in general, accompanied by a large bibliography. For a general study of the international development of art glass, see ADA BUCH POLAK, *Modern Glass* (1962). GEOFFREY W. BEARD, *International Modern Glass* (1976), provides an account of modern glasswork, with descriptions and illustrations of glass from various countries.

Comprehensive illustrative material on glass of ancient times is found in GUSTAVUS A. EISEN and FAHIM KOUCHAKJI, *Glass*, 2 vol. (1927); a scholarly survey is that of THE CORNING MUSEUM, *Glass from the Ancient World: The Ray Winfield Smith Collection* (1957). See also AXEL VON SALDERN, *Ancient and Byzantine Glass from Sardis* (1981). Roman glass in particular was treated exhaustively by ANTON KISA in *Das Glas im Altertum*, 3 vol. (1908, reprinted 1968). Basic treatises on pre-Roman glass include H.C. BECK, "Glass Before 1500 B.C.," in *Ancient Egypt and the East*, pt. 1, pp. 7-21 (June 1934); POUL FOSSING, *Glass Vessels Before Glass-Blowing* (1940); and BIRGIT NOLTE, *Die Glasgefäße im alten Ägypten* (1968). In addition to KISA (*op. cit.*), general books on Roman glass, such as MORDIN-JEAN, *La Verrerie en Gaule sous l'Empire romain* (1913, reprinted 1977); CLASINA ISINGS, *Roman Glass from Dated Finds* (1957); and DONALD B. HARDEN, *Roman Glass from Karanis Found by the University of Michigan Archaeological Expedition in Egypt 1924-29* (1936), are helpful for the understanding of this period. The latter has become a standard reference work for describing and cataloging ancient glass in general.

Western glass from the 5th to the 8th century is treated in detail by D.B. HARDEN, "Glass Vessels in Britain and Ireland, A.D. 400-1000," in *Dark Age Britain* (1956). Standard handbooks on Islamic and Western medieval glass are CARL J. LAMM, *Mittelalterliche Gläser und Steinschnittarbeiten aus dem Nahen Osten*, 2 vol. (1929-30); and FRANZ RADEMACHER, *Die deutschen Gläser des Mittelalters* (1933). Byzantine glass is described in JOSEPH PHILIPPE, *Le Monde byzantin dans l'histoire de la verrerie, V-XVI<sup>e</sup> siècle* (1970) and in VON SALDERN (*op. cit.*).

Basic handbooks on French and Belgian glass are JAMES BARRELET, *La Verrerie en France de l'époque gallo-romaine à nos jours* (1953); and RAYMOND CHAMBERON, *L'Histoire de la verrerie en Belgique du II<sup>e</sup> siècle à nos jours* (1955). WILLIAM A. THORPE, *A History of English and Irish Glass*, 2 vol. (1929, reprinted 1969), is a standard reference work on English glass in particular; HUGH WAKEFIELD covers *Nineteenth Century British Glass* (1961). German, Bohemian, and Austrian glass is treated exhaustively in ROBERT SCHMIDT, *Die Gläser der Sammler Mühsam*, 2 vol. (1914-27). For polychrome painting on vessels, see AXEL VON SALDERN, *German Enamelled Glass*

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## Glass Products and Production

The commercially manufactured material known as glass is normally a transparent, hard, brittle substance formed from certain liquids that have the property of cooling below their freezing point without crystallizing, thus becoming liquids of increasingly high viscosity (stiffness) until eventually they are so stiff that these liquids have the properties of a solid.

Of the many substances that can form glass, the most widely used is silica ( $\text{SiO}_2$ ), usually in combination with lime (calcium oxide,  $\text{CaO}$ ) and soda (sodium oxide,  $\text{Na}_2\text{O}$ ) in varying proportions, to make the soda-lime glass used for windows, light bulbs, bottles, and inexpensive tableware. Although glass could be made from silica alone, it would have an impractically high softening temperature, making it difficult to work. Nevertheless, it is the basic chemical nature of silica that determines both the structure of ordinary glass and the way in which it changes from a free-flowing liquid at high temperature to a virtually rigid solid as it cools.

The silica molecule can be visualized as a single atom of silicon, to the four bonds of which oxygen atoms are attached. The bond angles are fixed at  $108^\circ$  to each other, in three dimensions, at the centre. The oxygen atoms thus occupy the four points of a tetrahedron surrounding the silicon. Each oxygen atom plays a role in two such tetrahedra, but the bonds that unite it with its silicon partners do not lie in a fixed plane or at a precise angle. There is thus an almost infinite range of possibilities in the relative dispositions of the many tetrahedra that comprise even a minute speck of silica.

The silicon-oxygen bond is very powerful; considerable heat energy must be supplied if such material is to flow freely, because the fluid condition arises from the continued breaking, remaking, and rebreaking of this bond. Although heating and cooling crystalline silica can result in resumption of the crystalline form (and in materials that are not glass formers will do so), if cooling proceeds rapidly enough, the temperature at which transformation could occur is passed too quickly for the necessary rearrangement of atoms to take place; thereafter, the material is too stiff. The continuous random changes in the disordered structure are brought to a halt, and the structure remains as it was in its last fluid moment—in effect, a liquid whose molecules are immobilized.

Such a random liquid-type structure is a good deal more compact than one in which a state of maximum order prevails. It is full of cavities and holes that are of very considerable importance in practical glassmaking. If a metallic oxide is incorporated into the glass, many of these spaces will be occupied by metal ions, each of which will employ one of the bonds of an oxygen atom, so removing one of the props of the firm three-dimensional silica network. This, and the fact that the oxygen-ion bond is nondirectional, results in a much lower vis-

The  
molecNatural  
etching of  
glass

melted under certain reducing conditions, is heat treated. The particle size is critical, between 10 and 1,000 angstroms, and selective absorption then gives the glass its red colour.

**Nucleation and crystallization in glass-forming liquids.** It was noted above that a supercooled glass-forming liquid is in a metastable state (a stability that is maintained only by a slight margin over an unstable state) and that if crystals or crystal nuclei are introduced and freezing can begin, the crystallization will spread throughout the liquid.

Two aspects of the crystallization process must be considered separately, namely, the rates of formation of nuclei and their growth. So many nuclei are present in normal freezing processes that the crystallization process depends essentially upon the growth rate, and as this is negative above the freezing point, and very large and positive just below it, the liquid freezes at, or very near, the expected freezing point. For liquids (typically the highly viscous glass formers) that can be greatly supercooled, however, the crystallization rate also depends critically on the rate of formation of nuclei. Nuclei can be introduced from outside (heterogeneous nucleation) or can appear spontaneously within the supercooled liquid (homogeneous nucleation). Homogeneous nucleation occurs because of thermal fluctuations within the liquid; consideration of the contribution of the surface energy of the embryonic nuclei to their total free energy shows that, at any given temperature, there is a critical size below which the nuclei are unstable and redissolve, and above which they can grow.

Homogeneous nucleation

When nucleation and crystal growth occurs in glasses, it is known as devitrification. It is most marked in glasses in which the rates of nucleation and crystal growth nearly coincide when plotted as functions of temperature. Closeness of these curves results in nucleation and crystal growth over a wide temperature range. More stable glasses have a high viscosity at the freezing point, and crystal growth, which proceeds by diffusion process at the surface of the crystal, is slowed down. Heterogeneous nucleation, however, can still occur, especially at glass surfaces, when impurity particles are present.

Studies of nucleation and crystallization in glasses have been made in recent years. One result of these efforts was the discovery of a glass containing a small amount of dissolved metal, such as gold or silver, which, after exposure to ultraviolet radiation and subsequent heat treatment, develops a colour caused by the growth of small metal particles in the glass. If this photosensitive glass is heat treated further, the particles act as nuclei, and opalescent regions of the glass devitrification products are formed wherever the glass was exposed to the ultraviolet radiation. Much less resistant to chemical attack than the parent glass, these regions are dissolved away while the parent glass remains. By the commercial use of this process, pieces and patterns of desired shapes can be obtained—for instance, fluid amplification elements.

Glass ceramics

A glass has been produced that can be changed almost completely into crystalline material—the glass ceramic. In application, an article of suitable glass composition fabricated by the usual method is subjected to appropriate heat treatment to convert it into a ceramic. Such materials are extremely inert chemically and can be designed to have either zero or a very small expansion coefficient.

#### SPECIFIC PROPERTIES OF GLASS

**Mechanical properties.** Glass rods with untouched surfaces have a tensile strength of 500,000 pounds per square inch. By considering the energy changes involved in the surfaces formed by fracture the theoretical strength of glass is estimated to be about 1,000,000 pounds per square inch. Glass articles normally show strengths that are much lower, about 30,000 lb/in<sup>2</sup>; and this difference is due to submicroscopic surface flaws that, produced by the slightest contact with another body, act as stress magnifiers. Glass in ordinary use, therefore, is far less strong

than it would be in a flawless state. Although the have the same stress-reducing effect as dislocations in crystals, the exact identity of the flaws remains uncertain. Their presence, however, and number can be revealed by treating the glass with some modifying agent; for example, by immersing glass in molten lithium nitrate, sodium in the surface is exchanged for lithium. The thin layer that is produced is in tension when the glass cools and minute cracks develop at the flaws.

At temperatures below the transformation range the glass behaves as a solid and stresses will be present if the temperature varies within a glass object; a piece of glass cooled suddenly will contract more on the outside than on the inside; the further contraction of the outside is thus prevented and they are put into tension; the thermal expansion coefficient of a glass is (the expansion for each degree rise), the greater this tensile stress. Some glasses expand very little. Thus, fused silica has excellent resistance to heat shock, while borosilicate glass can undergo repeated reheating below the transformation range without cracking. It makes excellent ovenware.

In the transformation range the glass behaves simultaneously as a solid, an immediate elastic strain is produced when an external force is applied, the strain increases if the force is not removed. If the strain is continually reduced to keep the strain constant, the internal stress gradually disappears. The rate of this depends on the viscosity of the glass. When the coefficient of viscosity,  $\eta$ , equals  $10^{13}$  poise, the stress is lost about one minute. If a temperature gradient (a variation of temperature) exists in a piece of glass in the transformation range, the resulting stresses die away and the glass then has a temperature gradient but is stress free. On cooling to room temperature the hotter interior contracts more than the outer layers and is, therefore, under tension while the outer layers are in compression. Stresses remain until the glass is reheated to the transformation or annealing range. The principle is applied in annealing, which is a process of minimizing the internal stresses in glass by heating until they disappear. The glass is cooled slowly so that only very small temperature gradients, and ultimately, therefore, only very small stresses, appear. Unless a glass article is properly annealed, it might break spontaneously after cooling. Large stresses-free uncracked glass are rare and difficult to achieve. Annealing for exacting uses, such as in optical applications, moreover, involves more than the removal of thermal stresses; the atomic structure of the glass will vary within the piece unless all parts of the glass had exactly the same thermal history through the transformation range.

**Chemical properties.** Common glasses are chemically inert but reactions with many substances do occur. In contact with aqueous media the reaction between an exchange of hydronium ions,  $H_3O^+$ , for sodium ions,  $Na^+$ . (Hydronium ions exist in equilibrium with sodium ions,  $OH^-$ , in water.) Immediately, a surface layer is built up in which the sodium ions in the glass have been replaced by hydronium ions. For the reaction to continue, sodium ions must diffuse through the surface layer. While the silica itself dissolves slowly, the rate of diffusion of sodium ions and the removal of silica may be such that the surface layer, though moving into the glass, will remain at a constant thickness.

With commercial glasses these conditions are not attainable. The complexity of the process makes it difficult to design accelerated test procedures. Additives such as alumina may be added to increase the chemical durability of the glass. The action of these additives is to provide sites that hold sodium ions on the surface, producing a more uniform layer of sodium ions and lowering their rate of diffusion. The occupancy of these sites on the glass surface determines the behaviour of the glass when it is used as an electrode in determining hydrogen ion ( $H^+$ ) concentrations. When measuring hydrogen ion concentrations, it is important that the sites on the electrode be occupied by protons.

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**Critical appraisal.** The elucidation of higher classification of the cephalopods is fraught with difficulties. Early specialists divided the living cephalopods into Octopoda and Decapoda without relation to their internal structure; these were both placed in the Dibranchia, in contrast to all fossil forms, which were considered as Tetrabranchia because *Nautilus* has four gills rather than two. This unnatural classification, accepted by d'Orbigny in 1838, was gradually modified through the efforts of A. Naef and G. Grimpe and later workers to the form given above. Phylogenetic linkages are still highly theoretical, but with X-ray techniques that reveal soft parts in fossils, and with new paleontological finds the unfolding of the evolutionary history is in sight.

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(G.L.V.)

### Ceramics, Industrial

Industrial ceramics comprise all industrially used solid materials that are neither metallic nor organic. This definition expands the scope of ceramics far beyond the clay-based bodies of the potter and traditional industrial ceramics, as well as beyond the sand-dominated formulas of the glassmaker. In physical structure ceramics may be polycrystalline, glass, combinations of multicrystals with glassy phases, or single crystals. The universal properties of ceramics that account for their enduring utility include: mechanical strength in spite of brittleness; chemical durability (at both normal and elevated temperatures) against deteriorating effects of oxygen, water liquid or vapour, acids, bases, and salts at all concentrations, and organic solvents; hardness, contributing to resistance against erosion; and the ability to be decorated in a wide range of colours, textures, and designs.

This article deals primarily with the raw-materials, manufacturing processes, and glazing techniques for industrial ceramics. Industrial ceramics products include glass; cement; structural clay products; refractories (high-temperature materials); abrasives; whitewares; porcelain enamels or ceramic-metal systems; ceramic mineral preparations; and newer technical products such as electronic and nuclear ceramics, carbon, graphite, diamonds, and ceramic composites. For information on glass, see GLASS PRODUCTS AND PRODUCTION. Cement is covered in the articles CEMENT and CONCRETE. The article BRICK AND TILE PRODUCTION describes structural clay products. For information on abrasives, see ABRASIVES.

In addition to the primary producers of glasses, cements, and multicrystalline ceramics, there are numerous industries that rework the primary materials into sub-assemblies, components, or systems that have strategic and economic importance. Often these products, such as

computers, electric lamps, or television picture tubes, could not exist were it not for their ceramic constituents, yet the cost of the ceramic materials is small compared to the component and system values.

Functionally, ceramics technology draws upon the knowledge and skills of the pertinent sciences (physics, chemistry, rheology) and the design arts and the process capabilities of engineering to convert starting materials into new chemical and mineral compositions, with controlled microstructures (or, more broadly, character), dimensions, properties, and behaviour.

Though the glass and the ceramics industries share in common most raw materials, many unit operations and processes and the same underlying sciences, they have throughout the world generally developed as two separate industries. This division has arisen because of competition for some markets, as well as because of differences in the technologies. The same is true of the industries based on cement. In the following text, then, industrial ceramics derived by compacting particulates and subsequent heat treatment will be differentiated from the products of the glass and cement industries, in which the materials are first heated and then formed.

A new class of ceramic materials has been developed by first forming the material as a glass and then reheating to precipitate crystal phases with 50 percent or less residual glassy phase. These "glass ceramics" (known by a variety of other names in each country) can be made to approximate many traditional particulate-formed and sintered (heated but not melted to give coherence) ceramics in chemical and mineral composition; because there are fewer inherent restrictions on control over microstructure, these materials can have superior properties, such as improved resistance to heat shock.

**History.** Industrial ceramics may be said to have begun with the first barter of the potter's ware. Through ancient times and the Middle Ages, the techniques for making clayware continued to advance, and, with the coming of the industrial and scientific revolutions, the industries were ready to supply the scientist with porcelain for chemical experimentation and manufacturing and also to supply an increased demand for containers, tableware, sanitary ware, and construction materials.

Makers of industrial ceramics were thus prepared for the extraordinary demands brought by the 20th-century growth of the chemical, electrical, electronic, nuclear, automotive, and aerospace industries. For the electrical industry the first products were insulators, such as the familiar porcelain suspensions of transmission lines. For electronics the first new products were insulators for even higher frequencies, with the steatites (a class of magnesium silicate minerals) as the first novel materials. With the science explosion during and after World War II, the applications of ceramics in the electronic field grew to include compact capacitors, piezoelectric transducers, resistor and semiconductor compositions, magnetic materials (hard, soft, memory core, and microwave; see also FERRITES), and other energy converters. Improved compositions for automotive and aviation spark plugs led to high alumina (aluminum oxide) ceramics that have been applied to many mechanical, wear, and electronic uses, including even lamps. Nuclear reactors use ceramics for moderators and controls and the ceramic forms of nuclear fuels (uranium and plutonium) in fuel rods. Strong, hermetic seals of alumina and other ceramics to metals are vital in many applications.

**Particle bonding and packing.** The forming of ceramics involves particle technology, including size reduction (comminution), measurement, and separation; blending and packing of particles; surface chemistry and physics; rheology, or the flow of more or less plastic materials under pressure; and bonding of particles. Other sciences contribute to the understanding and control of heat treatment.

Ceramics came into being because of the useful rheological properties of the clay-water system, with its capability of being shaped, whether as a paste or as a fluid suspension or as a damp, crumbly powder. Modern industrial ceramics often replace clay with organic or in-

Universal  
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ceramics

Separation  
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and glass  
industries

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with which many legendary heroes are  
ed as being armed. The quarterstaff at-  
great popularity in England in the Mid-  
as. It was usually made of oak, the ends  
being shod with iron, and it was held  
both hands, the right hand grasping it  
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The staff was used as a foil, or prac-  
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of the period. In earlier times, it may  
ave been used as a practice weapon for  
ear and pike.

er-wave plate, in optics, a doubly re-  
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ology as an aid in mineral identification.  
polarization properties 10:941d  
ed light production 15:402f

er Latin, English LATIN QUARTER,  
of Paris south of the Seine River, cen-  
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eting place for artists.

arts association, and buildings  
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ilivre (1552), the fourth part of Fran-  
abelais's *Gargantua and Pantagruel*.

views of author 15:347d

a Roman and Portuguese unit of  
equivalent to 73.6 litres and 3.46  
respectively.

in and measures, table 5 19:734

nton, Enguerrand: see Charonton, En-  
mond.

in Sant'Elena, town, Cagliari prov-  
southern Sardinia, Italy, just east of Ca-  
city. It has distilleries, paper mills, cycle  
motorcycle factories, and candy manufac-  
Wine and cereals are exported, and  
are extensive salt mines nearby. The  
of St. Peter dates from the 13th cen-  
p. (1971 prelim.) mun., 29,944.  
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Sardinia 16:244

a widely distributed mineral of many  
that consists of silica, or silicon diox-  
ide. Quartz has attracted attention  
the earliest times; water-clear crystals  
known to the ancient Greeks as *krystal-*  
ence the name crystal, or more com-  
monly crystal, applied to this variety.  
The word crystal is an old German word of  
German origin, first used by Georgius  
in 1530.

Quartz has great economic importance.  
Varieties are gemstones. Sandstone,  
made mainly of quartz, is an important  
rock. Large amounts of quartz sand  
are used in the manufacture of glass and por-  
celain. In metal casting for foundry molds,  
quartz is used as an abrasive in sandpaper,  
grinding millstones, and grindstones.  
Silica is a high-grade refractory and is  
used as a flux in smelting calcareous ores.

Quartz and silica glass are used optically  
to transmit ultraviolet light. Tubing and vari-  
ous shapes of fused quartz have important  
industrial applications; quartz fibres are  
extremely sensitive weighing devices.  
Quartz occurs as a primary and essential  
constituent of some igneous rocks; it is abun-  
dant in pegmatites; and it is common in many  
metamorphic and crystalline schists. By the weath-  
ering of silicate minerals, silica passes into so-  
luble forms and is redeposited as quartz in cavities,  
veins, and joints of rock types. Quartz is  
resistant to weathering and forms the  
matrix of sands and sandstones. Extensive veins  
of quartz are frequent in schistose rocks. In  
some veins and lodes it is often the most  
valuable gangue (worthless rock) mineral. It  
occurs as pseudomorphs replacing other min-

erals and frequently is the replacement materi-  
al in petrified wood.

Quartz crystals have many interesting varia-  
tions. They may show a skeletal development,  
or they may have a helical twist. They may  
have successive layers of growth; if transpar-  
ent, the outlines of the inner layers may be  
faintly visible, giving "phantom" crystals.  
Many crystals have cavities, usually filled  
with a liquid (water, carbon dioxide, or a hy-  
drocarbon) and containing a movable bubble  
of gas. There are two types of quartz crystals,  
left-handed and right-handed; such crystals  
are said to be enantiomorphous. They are not  
superposable, but one is the mirror reflection  
of the other, like the right and left hands. This  
phenomenon is an optical feature related to  
the internal grouping of atoms, which actually  
consists of a spiral arrangement that reorients  
incident light.

Twin crystals of quartz are very common,  
particularly penetration twins such as Dau-  
phiné twins that consist of two right-handed  
or two left-handed intergrown crystals. Brazil,  
or optical, twins are intimate intergrowths of  
right- and left-handed crystals with laminae of  
one enclosed within the other. Both types of  
twinning may be present in the same crystal.

Because of its low symmetry, quartz is piezo-  
electric: a crystal develops positive and nega-  
tive charges on alternate prism edges when it  
is subjected to pressure or tension. The  
charges are proportional to the change in  
pressure. Because of its piezoelectric property,  
a quartz plate can be used as a pressure  
gauge, as in depth-sounding apparatus.

Moreover, if compression and tension pro-  
duce opposite charges, the converse effect is  
that alternating opposite charges will cause al-  
ternating expansion and contraction. A sec-  
tion cut from a quartz crystal with definite  
orientation and dimensions has a natural fre-  
quency of this expansion and contraction (i.e.,  
vibration) that is very high. Properly cut  
plates of quartz may have frequencies mea-  
sured in millions of vibrations per second and  
are used for frequency control in radio and  
other electronic communications equipment  
and for crystal-controlled clocks.

When heated, quartz undergoes a series of  
remarkable changes. At ordinary tempera-  
tures it exists as  $\alpha$ -quartz, but at 573° C  
(1,063° F) it passes over into  $\beta$ -quartz, with a  
change in symmetry and an alteration in other  
properties; at 870° C (1,598° F) this  $\beta$ -quartz  
changes to  $\beta$ -tridymite, and again at 1,470° C  
(2,678° F) changes to  $\beta$ -cristobalite. These  
changes are known as inversions. The inver-  
sion from  $\alpha$ - to  $\beta$ -quartz is reversible, so that  
quartz is always the  $\alpha$  form at ordinary tem-  
peratures. After  $\beta$ -tridymite or  $\beta$ -cristobalite  
are formed, they remain as tridymite or cris-  
tobalite, but upon cooling they invert to  $\alpha$ -  
forms that may exist for indefinite periods.  
Accordingly, all three forms occur in nature.  
The six crystalline modifications have closely  
related structures in which each silicon atom  
is surrounded tetrahedrally by four oxygen  
atoms. Adjacent tetrahedrons are linked by  
sharing of oxygen atoms, and the various  
modifications differ only in the arrangement  
of these linked tetrahedrons.

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quartzarenite, sandstone containing 95 per-  
cent or more quartz grains.

sandstone types and composition 16:215a;  
illus. 214

quartz-crystal clock, timekeeping device  
actuated by an electric motor supplied with  
alternating current, the frequency of which is  
accurately regulated by the resonance of a rod  
or disc of piezoelectric quartz.

construction and accuracy 18:415h  
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quartz diorite (petrology): see tonalite.

quartzite, sandstone that has been converted  
into a solid quartz rock. Unlike sandstones,  
quartzites are free from pores and have a  
smooth fracture; when struck, they break  
through, not around, the sand grains, produc-  
ing a smooth surface instead of a rough and  
granular one. Conversion of sandstone to  
quartzite may be accomplished by precipita-  
tion of silica from interstitial waters below the  
Earth's surface; these rocks are called or-  
thoquartzites, whereas those produced by re-  
crystallization under high temperatures and  
pressures are metaquartzites.

Quartzites are snowy white, less often pink  
or gray; they commonly have a fine angular  
jointing and break up into rubble under frost  
action. They yield a thin and very barren soil  
and, because they weather slowly, tend to  
project as hills or mountain masses.

The term quartzite implies not only a high  
degree of hardening (induration), or "weld-  
ing," but also a high content of quartz; simi-  
lar rocks that contain appreciable quantities  
of other minerals and rock particles are im-  
pure quartzites, more appropriately called  
graywacke, litharenite, sandstone, etc. Most  
quartzites contain 90 percent or more quartz,  
but some contain 99 percent and are the larg-  
est and purest concentrations of silica in the  
Earth's crust. Pure quartzites are a source of  
silica for metallurgical purposes and for the  
manufacture of silica brick. Quartzite is also  
quarried for paving blocks, riprap, road metal  
(crushed stone), railroad ballast, and roofing  
granules.

In microscopic section the clastic structure of  
some quartzites is well preserved; the round-  
ed sand grains are seen with quartz over-  
growths deposited in crystalline continuity, so

APPENDIX D—Table of Authorities

- (1) *In re* Buehler, 515 F.2d 1134, 185 USPQ 781
- (2) *In re* Rosenburger et al., 55 CCPA 880, 386 F. 2d 1015, 156 USPQ 24
- (3) Manual of Patent Examining Procedure (M.P.E.P.)

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